system to the site of its deposition at the connecting link between the two chlorophyll systems.

We have thus expanded a system originally proposed some years ago, at which time we could not adequately distinguish between electron migration and hole migration in the chlorophyll array (*6*). In the present proposal it now appears that in the green material, both systems are possible transport systems. The primary quantum conversion and the separation of oxidant and reductant would thus depend in both pigment arrays on semiconduction mechanisms—hole migration on one side and electron migration on the other. While the low-temperature reversibility of spin signal and optical-density changes is strong evidence for the proposed hole migration system, corresponding evidence is still lacking for the electron migration system.

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The Man-Computer Relationship

The potential contributions of computers crucially depend upon their use by very human human beings.

David L. Johnson and Arthur L. Kobler

Recently Norbert Wiener, 13 years after publication of his *Cybernetics*, took stock of the man-computer relationship (*1*). He concluded, with genuine concern, that computers may be getting out of hand. In emphasizing the significance of the position of the computer in our world, Wiener comments on the crucial use of computers by the military: "it is more than likely that the machine may produce a policy which would win a nominal victory on points at the cost of every interest we have at heart, even that of national survival."

Computers are used by man; man must be considered a part of any system in which they are used. Increasingly in our business, scientific, and international life the results of data processing and computer application are, necessarily and properly, touching the individuals of our society significantly. Increasing application of computers is inevitable and requisite for the growth and progress of our society. The purpose of this article (*2*) is to point out certain cautions which must be observed and certain paths which must be emphasized if the man-computer relationship is to develop to its full positive potential and if Wiener's prediction is to be proved false.

In this article on the problem of decision making we set forth several concepts. We have chosen decision making as a suitable area of investigation because we see both man and machine, in all their behavior actions, constantly making decisions. We see the process of decision making as being always the same: within the limits of the field, possibilities exist from which choices are made. Moreover, there are many decisions of great significance being made in which machines are already playing an active part. For example, a military leader recently remarked, "At the heart of every defense system you will find a computer." In a recent speech the president of the National Machine Accountants Association stated that 80 to 90 percent of the executive decisions in U.S. industry would soon be made by machines. Such statements indicate

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a growing trend—a trend which need not be disadvantageous to human beings if they maintain proper perspective. In the interest of making the man-machine relationship optimally productive and satisfactory to the human being, it is necessary to examine the unique capabilities of both man and machine, giving careful attention to the resultant interaction within the mixed system.

Basic Parameters

In any analysis of the types of problems which may, or should, be solved by automatic methods, the decision capability of the machine is fundamental to the entire solution. Whether the problem is the addition of a series of numbers or the firing of a retaliatory nuclear weapon, the computer can act only through the processing of a series of yes-no decisions. Much work has been done in the definition of decision structure. The fundamental decision element is one of binary choice with one or more inputs and two outputs (or at least a single output capable of bi-stable condition). Such basic decision elements may be combined to provide decision systems as complex as the application requires. The decision "Is A greater than B?" may be considered a single basic decision (*3*). As input, we have two variables, the magnitudes of A and B. The decision element in this case can be a simple comparator. The output may be either a "yes" or a "no." The inputs must accommodate variables of specified or unspecified limits. The output is limited to a simple binary choice, the forms of which are fixed. There is no room for a "maybe" answer within the single decision unit. Of paramount significance, however, are the decision parameters which are neither input nor output but which determine the structure of the actual decision apparatus. Thus, in the foregoing example such parameters might include the following considerations: (i) *greater* should be defined; (ii) both quantities are (or are not) represented in the same number systems; (iii) infinite magnitude is (or is not) allowed; and (iv) magnitude relates only to the comparison (or signs must be considered). Clearly, these are just samples. Many other elements must be fixed before the decision structure is complete.

In cases of equipment design, such "basic" parameters usually exist within the discipline of a determining operation and may be resolved without extensive ambiguity. In more complex decision simulation, the parameters may vary from one decision to another in ways so subtle as to elude identification.

In considering decision characteristics in their relationship to man and the computer, a broad examination of the generally relevant field is required before adequate definition within restricted specific subfields is possible. One must recognize that the general field encompassing the environment and context of any decision determines to a large extent the type of decision process used, as well as the parameters of the decision structure. Although the field forces will affect both input and output forms, the most insidious effect will be upon the parameters relative to the decision itself.

In decision situations one important factor is the amount or degree of input information available. There may be little information about the choices, all the necessary information, or a confusing redundancy or superfluity of information. The evaluation of the output, of the decision made, will be influenced by the criteria available for judging it. We can have absolute, defined criteria or literally none at all. In the latter case, a number of "reasonable" men (or rational machines) may arrive at a number of equally satisfactory decisions; moreover, each of the choices, if implemented, may result in equal success-failure probabilities.

"Routine" and "Special" Problems

Today, computers are used most in dealing with what may be called "routine" problems, as contrasted with "special" problems. "Routine processing" can be used when the problems are subject to solution by specific, well-defined methods; when the validity of the solutions can be appraised; and when all parameters are defined. "Routine-direct" decisions are most often made in the physical sciences, in a system so bounded that the human response or cause is not considered. The decision structure is defined, as are the inputs, the outputs, and the decision parameters. In most cases the variables are measurable, or, at the least, probabilities are available, together with adequate information as to their reliability. Within a given solution predetermination of particular decision paths may be impossible, but implicit in the system is the characteristic that all possible decisions are recognized and considered within the rigid decision structure.

Different from the routine-direct solutions, but still within the defined "routine" category, are the routine-learning solutions, which involve training with, and use of, computers as learning machines. These are discussed later in this article.

Problems susceptible of routine-direct solution arise within limited environmental fields. Such problems lend themselves readily to automation. Our "special processing" category of decision problems includes all problems outside the rather restricted "routine" category. Most routine problems are part of systems which are themselves special in nature. Thus, to use, and evaluate the meaning of, a routine solution in its application within the total environment is a special problem which requires evaluation in the field of human reaction: How is the routine information output to be used?

Routine-direct processing may be applicable to dull, time-consuming, massive clerical jobs, or to problems requiring tremendous amounts of prescribed, iterative calculations. Sometimes, however, such a job may appear routine to some yet special to others. These variations in categorization are not, for the most part, variations in the means of calculation or solution but variations in the input parameters upon which the decision is to be based. The variations appear as soon as man is considered a part of the system to be examined. For example, in Ohio, computers "study possible rights of way, tot up the estimated property values involved in purchasing them, and pick out those which best combine cheapness and directness and ease of construction. Then they work out most of the engineering problems for the new highways to be built over them (*4*). Some Seattle citizens feel that their beautiful city is being destroyed by a cheap, direct, easily constructed, but ugly freeway, which has taken over some of the most beautiful public park land. For them, then, the Ohio computer problem is not routine; all necessary and appropriate information is not available, and there is no clearly defined criterion of output. The problem is a special one; beauty, they feel, should be one of the parameters. How does one measure beauty? The problem here is not one of computer function; highway engineers could reach a like conclusion more slowly and less efficiently. The problem lies in the human response to a computer output: the computer has delivered results, and they have the aura of finality and correctness.

Clearly, the special area of decision making has been the unique property of human judgment. With the contemporary state of knowledge, this fact is both reasonable and proper. Inputs, parameters, and outputs for special problems are poorly defined and impossible to measure. Even on a probabilistic basis, little information is available and statistics are inadequate. In most cases, elemental decision probabilities may be determined with some validity, but information as to the relationship of the decision elements in the total system are unique in each given environment and extremely difficult to fix by either joint or conditional probabilities. Clearly, more definitive understanding of the human complex is required before all phases of decision systems which include human parameters may be resolved. It is not surprising that it is currently difficult to find decisions involving human reactions within a system which can be adequately and generally treated by mechanized simulation.

In this context, then, we see dangers which fall into two categories: first, in the present state of our knowledge we may too easily overlook crucial parameters in the decision situation, parameters which do not permit processing—for example, values; second, we must be aware of the frailty of man qua man, particularly of man in our complex world. Man exerts a dominant influence on the use of computers and on the man-machine relationship. In the remainder of this article we will consider these two general areas, which often overlap.

Parameters of Value

Values, broadly conceived, are required for the solution of any decision problem. If the problem is dominated by a rigid and well-measured scientific discipline, the values may simply be mathematical—for example, that 3 is greater than 2, and that 5 times 4 equals 20. The discipline itself has defined and fixed the necessary assumptions as to the meaning of the operations and the number system intended and has set a scale of values under which the solution is to be obtained. Thus, for even the most routine tasks, values are programmed in; every problem statement or program inherently contains what is wanted, or valued, by the programmer. In cases of routine-direct solutions, the parameters are fixed by the scientific discipline under which the problem is being solved.

Values are also inherent in the nature of the problem itself—that is, in the solution which the computer is asked to deliver and the claims that are made as to the use of the solution. One programmer may value cheap, efficient roads and may ask the computer to provide him with specifications for such roads, whereas another may value expensive, beautiful roads. In this second instance, the values are less clear-cut and more difficult to measure: What is beautiful? How much should be spent for how much beauty? Not only are such parameters difficult to define and measure; they may in some instances be difficult to admit or recognize. For example, in personnel work, an individual who may not be doing measurably satisfactory work may be recommended by the machine for dismissal. In the event the individual proves to be the aunt of the vice-president or the cornerstone of the morale structure of the office, dismissal may not be the most profitable course. It would be extremely difficult for the administrator to define the office social structure or to admit on the immortal program tape that he valued his job more dearly than his business efficiency. The values at such points become difficult to rank, to relate, and often to bring to the level of conscious realization. And yet such values exert a dynamic influence upon specific and critical choices.

In cases of routine-learning solutions, the values are fixed as classes rather than by specific ranking. That is, it is possible for the machine to rank and order a prescribed set of values on the basis of success in repetitive learning procedures as currently performed in mechanized games of checkers and chess. The existence of the fundamental values, then, must be recognized in the problem structure; the use to which they are put and the effect which they have upon the final result are fixed by the learning process of the computer. Again we see the possibility that certain entries within the decision system structure will be neglected; and, equally important, in cases where the goal of the learning game is poorly defined, the use to which the values and responsibilities are put may yield results which are far from acceptable in actual situations.

Within the category of problems which are inherently special in nature, the parameters, as well as their use within the system structure, are undefined or incompletely defined. In such special solutions one must interpret results of computer simulation as limited in meaning and must impose severe restrictions upon the use of the special solutions in the light of their effect upon the humans for whom they are developed.

Among the special problems, moral values and prejudice belong in the large family of values over which there is no governing discipline which applies to all people. We will discuss problems involving ethical choices, although, in the context of computer operation, we will not differentiate them from the total value problem.

One major problem in working with value parameters in decisions falling outside the routine-direct category is the sensitivity of the balance of the multiplicity of values involved, and of their interrelationships. Even if it were possible to enumerate, rank, and relate the various values in a given special decision process, it is improbable that the parameters would remain fixed for the same decision in a slightly different context.

Where other than rigid values are involved in the decisional setting, another closely related parameter often is relevant. We talk here of responsibility, for the decisional situation is clearly different when the setting is that of an abstract "game" and when it is one in which the decision is to be actually implemented, and where man is directly responsible. Responsibility, as we see it, means that the cause lies with the decision maker and the decision concerns a personally relevant action. Situations of individual responsibility, and the concurrent increased emotional significance, take on the character of uniqueness, and probability guides are not satisfactory. Therefore, although two different situations may require solution by the same decision structure, the parameters fixed by responsibility will greatly modify the processing of the input. The current discussion of bomb-shelter morality provides an example of this type of problem. In such situations it may be that the parameters of the decisional field are not definable until after the choice has been made, after the decisional action has been taken; it is only then, and not before, that the values of decision maker are defined.

Results of Human Limitations

The consideration of values in such decisional contexts leads directly to our concern with the frailty of man. Two of the most responsible and respectable of contemporary social-psychological commentators have characterized today's man as increasingly "other directed" (*5*) and pressed toward "escape from freedom" (*6*). Faced with increasing complexity and massive responsibility, man has tended more and more to work in groups, and committee decision is now commonplace. One major consequence is the decrease in individual identity and the loss of individual responsibility. The computer, coming at this time in man's progress, can and does play a special role in enabling man to escape the freedom of responsible choice. After all, who can be held responsible for a decision by a computer? Moreover, the increased complexity of the world man faces makes him more aware of his own limitations. Such awareness leads to feelings of inadequacy, and the desire and need for, someone or something outside himself that has the qualities he feels lacking in himself—solidity, infallibility, and so on. He looks for the father, the leader, God, scientific truth. The computer has the proper aura. It can be perfect; it can be right; it can be very nearly infallible; it can produce the truth. Already, in its infancy, it can solve problems quickly that would have taken man many lifetimes to solve. It can make systematic sense out of a gigantic mass of apparently disorganized information. In its solid, efficient, light-flashing way it acts without obsessive hesitation—as if it is sure, as if it knows. It acts without emotional involvements, without commitments, in a manner which can be called objective.

Most subject to the hypnotic effect of the computer are those whose direct contact with computer operation and programming is limited. Scientists trained in the design and operation of computing devices frequently must recognize the limitations of mechanization in communication with human systems. Often, however, these men are the very ones who are working within such a rigid discipline that computers are able to solve their problems, and they may read into this ability the ability to solve all problems.

In this setting there exists a considerable danger that complex decision systems involving human parameters will be broken down into routine segments which are more or less independent of human reaction, and that the combination will then be called a credible simulation of the total system. Such a danger has always existed in all categories of problem solution; however, with the advent of increasingly effective computers, the danger is becoming more seductive and more far-reaching in the scope of its influence. Such a process effectively rules out true simulation but provides the satisfaction of optimum mechanization, with resultant speed and accuracy. Also, there is an attractive but dangerous precedent for restricting value parameters in the interest of simplicity and neatness; the result is a superficial and predictable decision which may be satisfactory in a "game" simulation but is disastrous in application. Any method which ignores or explains away that part of the subject matter with which it cannot deal is, or can be in the long run, worse than useless. It raises false hopes, and it misleads if it promises what it cannot fulfill. Under the guise of reliability, usually in cases where general reliability cannot be measured or recognized, unimaginative and partial results may be accepted as accurate simulation. One is tempted to accept a completely accurate processing listing of economic factors inherent in a given society as an analysis, instead of treating it as the routine part of a complex decision system whose validity can only be evaluated in the light of its effect on the human environment. One is tempted to talk of the machines as potentially artistically creative. Machines can create; they can and do write music and plays. Speaking of man, Arthur Miller said recently, "I think there is one confusion to be cleared up. While it is true that all of us are creative, not many of us are artists. That is the crucial difference." The "Illiac Suite for String Quartet" is the result of a creative act, but that does not make it artistic, and artistic values are the appropriate ones to use in evaluating musical creations.

One is tempted, too, to evaluate the effects of a nuclear deterrent force in terms of routine decision making as to casualties or economic loss, without an actual study of exactly what human parameters, at a given time, are appropriate to the basic problem of deterrence. Fighting nuclear war on the machines is obliquely related to the question of adequate deterrence; the latter is, however, at least as much a psychological as a military problem and is very "special" indeed. Here again, issues involving values as applied by man may be fed into a computer for analysis and decision, together with values implicitly if not explicitly programmed. The computer is programmed for a particular solution to be put to a specific use. There is no possibility of avoiding consideration of such values; with or without the computer they are a part of the total decisional field. Machine quantification may make it appear that such values are not appropriate, but amorality is at least as serious as immorality, and a problem may be so reduced that its solution bears no real meaning.

The question of how output data are to be used is, to our mind, crucial and a special problem. Certainly, the ability to gather and to use information carries power with it. Once knowledge is openly available, its use by the public is often far removed from the conception of the discoverer. Present-day nuclear physicists know too well the various uses of knowledge. Present-day medical knowledge is being used to produce biological weapons to destroy man's life and to produce techniques to save man's life. The use, then, of output data often involves ethical questions.

Our concern with the parameters of value and responsibility in decision making stems from our view that machines are now making, and will continue to make, decisions in which such issues are significant and in which they are consistently ignored. In too many cases the computers are instrumental in decision making to the extent that they essentially determine the decision output because of their operational mode and man's reaction to them. In many of these cases the routine solutions are theoretically to be used as data to be inserted into a human decision system. Too often, however, the information is presented in such a way as to imply that the human decision is redundant.

It has been stated (*4*) that "the computer systems already operational are impressive enough, but they do not compare with the sophisticated systems that are under study and on order for delivery [to the Federal Government] in the early 1970's. In some of them the on-line concept is carried so far that if a reconnaissance satellite should send in a report of Russian rocket launchings, it would automatically generate a retaliatory battle plan from one computer that would automatically be put into action by other computers, aiming and firing Atlases, Titans, and Polarises on and under land and sea. The only interruption in the sequence, except for the system's own safety checks and repeats, would be a token one of a few minutes for the President of the United States to exercise freedom of will and say 'fire.' What to do about this choiceless choice, how to extend the time for decision and make the machines as accurate as possible, is the subject of serious concern and study by several groups of computer men who address themselves exclusively to command and control problems." With the increasing efficiency of missile systems the problem of time becomes increasingly important, and the use of computers in such a situation as that described seems both appropriate and necessary. But the crucial factor, as we see it, is the President's choice, which, like any responsible decision, is neither "token" nor "choiceless." While computer men are trying to make the machine as accurate as possible, others, including the President, are concerned with this choice, as they should and must be. A Russian rocket launching may be an accident, or it may be pointed at the Chinese. These are crucial issues, on which the survival of our society may depend, and they are part of the decision environment. Thus, while all pertinent decision input should be determined by the most efficient means, we must use extreme caution not to magnify the significance of the computer processing to such a degree that it appears to be the decision itself.

Machine-Learning Systems

Man's frailty plays a crucial part, too, in relation to learning machines, even though they have not yet been developed to a point where they are applied in matters critical to human welfare. The successful learning programs have been applied principally to such games as checkers and chess, in which they show remarkable success and promise. Current learning techniques, as applied to computers, demand that the rules of the game be clearly stated, that the goals be exact and easily measurable, and that the game be of such duration that the machine can learn through repetitive playing. While these routine-learning applications are vastly different from applications in the routine-direct category, it should be clear that, although the value and responsibility parameters are defined, fixed, and recognized, the computer essentially orders and ranks the parameters through the process of repetitive learning, in such a way as to yield successful completion of the game. The parameters must be defined, then, but the computer is at liberty to weigh the values and to decide which ones should be used in determining the tactics and strategy that will yield success. It should be emphasized that such programs do not at present allow the computer to develop basic parameters—for example, in a game of checkers, to decide that "one square at a time" actually means "two squares at a time." These games are set up within such rigid disciplines that the defining rules of the game and the fixed goal of success fix the decision parameters. But in the realm of learning machines and their operation, one result of the program techniques is removal from the mind of the designer, and of the operator, of an effective understanding of many of the stages by which the machine comes to its conclusions and of the actual long-range intentions of many of the operations. Wiener states (*1*): "This is highly relevant to the problem of our being able to foresee undesired consequences outside the frame of the strategy of the game while the machine is still in action and while intervention on our part may prevent the occurrence of these consequences." Because of the time differential—that is, the balance between the speed of the computer and that of man's operations—the communication between man and machine is incomplete.

Machines can be trained to learn, and computers undoubtedly show originality, particularly in game learning, not only in short-term tactics but also in long-range strategy. The machines can transcend their makers and programmers, and the end point may be creative and new, but not necessarily appreciated by the programmer. Because of the time differential, and of inadequate knowledge of the learning machine's tactics and strategy, either man must depend on the machine or he must not. This parameter of time balance is quite different from the parameters hitherto discussed. Even when a problem is one of routine decision within the rigid discipline of mathematics, it is common to find the automatized decision made with such speed that it must be used before it can be completely checked. Checking in this case does not imply possible fallibility of the decision-making mechanism but incomplete recognition of the decision and its environment by the programmer. One acceptable mode of checking is simulation—that is, actual trial of the decision-making operation. This is valid where every possible case can be simulated. In the vast majority of significant decisions, however, such an extensive simulation is impossible, or all possible occurrences cannot be recognized.

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Humans within the decision system are more fallible and less apt to operate in a well-organized, accurate manner than computers. However, human solution involves times which are compatible with human review. Humans have sufficient time to use their self-organizing facilities to vary the perspective of the problem in time as it progresses—for example, to vary parameters, and sometimes the actual input. The time balance is not necessarily dangerous; its very existence is one of the benefits of automation. However, it is a parameter of decision processes which should be consistently considered. Particularly in respect to learning systems in which the goals and rules are well defined, the stratagems used to reach the goal, as developed in the solution, may be, as was noted earlier, completely incompatible with the original goals. If the entire operation takes place at such a rapid rate that only success in reaching the goal can be evaluated before the process is put into effect, the time-balance problem is critical. And if, during the course of a machine action, we stop the machine because we do not like or understand a given tactic, we will destroy the total strategy and make the use of a computer pointless. It is doubtful whether man, faced with a problem he has given to the machine, can comfortably contradict, stop, or limit the learning program. It is far more likely, in the man-machine relationship, that man will accept the machine's decisions, whether or not he understands them. The fact that we cannot yet include in mechanized processing the complete and necessary value and responsibility parameters is easily overlooked in the light of positive values such as efficiency, speed, accuracy, and objectivity.

Machines can and do simulate events that cannot be studied in actuality. Examples are the action of a petroleum cracking column, a nuclear attack, the burning of a solid fuel inside a rocket, or the flight of a space ship, as well as business procedures. Mechanized business games have become an integral part of training in certain universities and are used by many large industrial concerns in the training and evaluation of personnel. These games, like war games, are not basically in the learning category but operate with predetermined and fixed values. Only in the reaction of the human players as a part of a total system do the games fall within the special-problem group. The human reaction to the game, however, is often intense. There have been instances at the University of Washington of students dropping from class because of the emotional reaction to the computer game. Although industrialists explain that the game outcomes will not be used in personnel evaluation, the players feel tense and threatened. While in most of the games the players are not playing against the computer but against each other through the computer, the introduction of a mechanized intermediary of such precision and speed increases the threatening aspects of what is called a "game." Because such games cannot possibly include all of the variable parameters of actual business, it is sometimes possible for players to "beat" the game by extremely improbable or unethical decisions. Business games of this type are obviously valuable in emphasizing "cause and effect" truisms of specific facets of business. Only when it is assumed that a partial simulation of human reaction and economic structure is a complete and accurate simulation does the problem become manifestly dangerous. As in the other examples discussed, as long as the routine solution is admitted to be a routine solution and used only as a partial simulation of systems involving humans, the solution can be used to decided advantage.

The attitudes of the participants when "playing" with a computer are worthy of note. Here again we see a reaction of humans forced to subject their human—and therefore incompletely defined—decision systems for evaluation by the computer, which has been socially accepted as totally objective and accurate.

The human reaction to war games is different. War, like business and like human mental functions such as problem solving, can be simulated, and the simulation may be of great value. The danger lies in believing that in the results of such simulation one has the complete truth. For example, it has been claimed that predictions of victory in war games are becoming increasingly accurate. In this claim the role of man's fantasy is clear. Military leaders need ways of estimating possibilities and probabilities in planning for war; the machine can do more than man, can handle complexities systematically, and can study far more cases and far more variable systems. Yet it is obvious that the input information must be grossly inadequate, especially in planning for the "new" nuclear warfare. There is no way to completely estimate or evaluate what would happen in a "real" war. And yet, how are these results used? Mechanized war games are used, like business games, to rapidly obtain experience and training and to relate cause and effect. In both instances the games are considered useful bases of implementation. Although man knows that the simulation is imperfect, it is all too easy for him to feel that success in the game is indicative of success in the real situation; that tactics and techniques which are effective in game playing are effective in actuality. The mechanized process, because it catches many of the pressures and human reactions of actuality, seems to provide precise objectivity which permits mechanical evaluation of the strategy or tactics involved. Man's frailty makes him wish to shunt off complex decisions to the machine, with its apparent logic, reason, objectivity, and superhuman capacity. Unfortunately, it is in these most important decisions—involving massive responsibility and reaction and concomitant meagerness of information input and criteria of output evaluation—that man most needs help. Unfortunately, it is in these very cases that the machine *must* be used solely as a routine processing device, that it must not be made to take responsibility from man.

While applications involving military operations and national security emphasize the extreme significance of the man-computer interface problem, other, less traumatic, applications and examples should not be neglected. As has been stated, actual machine-learning techniques are not being widely applied at present. Essentially, all computer applications have been handled as routine-direct problems, even those involving war games or business games. The computer is not directly allowed to map original strategy or tactics; it follows specified cues and preestablished values to organize vast quantities of data with its inimitable speed and accuracy. To our mind it is in these contemporary solutions that the essential parameters of values, the time-balance, and the human response to the mechanized system must be analyzed with extreme caution. It should be clearly understood that in calling for caution we do not imply that all use of computers is dangerous, or, for that matter, that any computer application must in itself be dangerous. Rather, it is the use of the computer results that concerns us. In the field of mechanical translation of languages, the routine-direct processing is a great complex of decision systems. In the present phase of development, translation errors are usually recognizable, and the problems of the computer-human relationship are more often matters of irritation than of danger. Caution is needed relative to this decision operation of the computer only as regards the use to which the translation process is put. If translation output were to be placed directly into legal or business documents, serious problems could arise. However, as long as the quality of the translation is recognized for what it is, this esoteric process should not be considered to intrude upon the man-computer relationship.

Conclusions

The levels of human knowledge of the environment and the universe are increasing, and it is obviously necessary that man's ability to cope with this knowledge should increase—necessary for his usefulness and for his very survival. The processes of automation have provided a functional agent for this purpose. Successful mechanized solution of routine problems has directed attention toward the capacity of the computer to arrive at apparent or real solutions of routine-learning and special problems. Increasing use of the computer in such problems is clearly necessary if our body of knowledge and information is to serve its ultimate function. Along with such use of the computer, however, will come restrictions and cautions which have not hitherto been necessary. We find that the computer is being given responsibilities with which it is less able to cope than man is. It is being called on to act for man in areas where man cannot define his own ability to perform and where he feels uneasy about his own performance—where he would like a neat, well-structured solution and feels that in adopting the machine's partial solution he is closer to the "right" than he is in using his own. An aura of respectability surrounds a computer output, and this, together with the time-balance factor, makes unqualified acceptance tempting. The need for caution, then, already exists and will be much greater in the future. It has little to do with the limited ability of the computer per se, much to do with the ability of man to realistically determine when and how he must use the tremendous ability which he has developed in automation.

Let us continue to work with learning machines, with definitions of meaning and "artificial intelligence." Let us examine these processes as "games" with expanding values, aiming toward developing improved computer techniques as well as increasing our knowledge of human functions. Until machines can satisfy the requirements discussed, until we can more perfectly determine the functions we require of the machines, let us not call upon mechanized decision systems to act upon human systems without intervening realistic human processing. As we proceed with the inevitable development of computers and means of using them, let us be sure that careful analysis is made of all automation (either routine-direct, routine-learning, or special) that is used in systems of which man is a part—sure that man reflects upon his own reaction to, and use of mechanization. Let us be certain that, in response to Samuel Butler's question (7), "May not man himself become a sort of parasite upon the machines; an affectionate machine tickling aphid?" we will always be able to answer, "No."

References and Notes

1. N. Wiener, *Science* **131**, 1355 (1960).
2. The study of which this article is a part is supported by the Air Force Office of Research.
3. Many basic decision units may be required by the logical-design engineer to accomplish the operation of the single basic decision.
4. D. Bergamini, *Reporter* (17 Aug. 1961).
5. D. Riesman *et al.*, *The Lonely Crowd* (Yale Univ. Press, New Haven, 1950).
6. E. Fromm, *Escape from Freedom* (Rinehart, New York, 1941).
7. S. Butler, *Erewhon* (Doubleday, New York, 1872).

News and Comment

NIH Foreign Grants: Reappraisal Seeks To Develop Policies for Supporting Research Abroad

The National Institutes of Health is reappraising its foreign grant program, which, like most NIH activities, has grown at an incredible pace over the past few years. There is no desire or intention to cut down existing support for foreign scientists, nor is it likely that the program will eventually be reduced or leveled off. But NIH, now that it is deeply involved in the support of research in the laboratories of other nations, is looking at the broader implications of its foreign involvement and is seeking to develop more clearly defined policy lines.

A spur in this direction is provided by the embarrassment of the Bertil Bjorklund case, involving a Swedish cancer researcher who was receiving NIH support at a time when he was repudiated by his Swedish colleagues. It would be incorrect to ascribe too much significance to the case, since it can legitimately be viewed as the sort of thing that easily could happen in any large-scale operation. But the case illuminates the question of what NIH is seeking to obtain when it finances research abroad. It also demonstrates that, while it is better to give than to receive, philanthropy is a difficult business, especially when the recipients are members of a foreign scientific community.

It is generally known that NIH finances most of the biomedical research in the United States, but few people have noticed that NIH has also become an important source of support for a great deal of scientific research effort abroad. NIH's foreign grant activities began in 1954 with 11 awards totaling $95,000. Last year it made 800 grants for a total of about $14 million. This year the total is expected to be about $16 million, nearly double NIH's entire budget for 1947. The foreign grants, distributed among nearly 50 countries, are trifling in comparison with the amount NIH will award for domestic grants this year (about $450 million), but in some cases they amount to a sizable percentage of the medical research expenditures in the recipient countries. For example, Sweden, where NIH has one of its largest programs, received $1.4 million last year, which was about 10 percent of the amount the Swedish government put into biomedical research. The percentage in this case is uniquely high, but even where it is lower, the NIH support takes on considerable significance within the scientific community. The largesse that is generally enjoyed by American medical research is unknown abroad, and, therefore, every source of support is important.

The reappraisal of NIH's foreign programs is being conducted by its